RADIO RELAY APPLIANCE ACTIVATION

BACKGROUND OF THE INVENTION

1.   Field of the Invention

The present invention relates to remote control of appliances such as,
for example, garage door openers.

2.   Background Art

Home appliances, such as garage door openers, security gates, home
alarms, lighting, and the like, may conveniently be operated from a remote control.
Typically, the remote control is purchased together with the appliance. The remote
control transmits a radio frequency activation signal which is recognized by a
receiver associated with the appliance. Aftermarket remote controls are gaining in
popularity as such devices can offer functionality different from the original
equipment remote control. Such functionality includes decreased size, multiple
appliance interoperability, increased performance, and the like. Aftermarket
controllers are also purchased to replace lost or damaged controllers or to simply
provide another remote control for accessing the appliance. An example application
for aftermarket remote controls are remote garage door openers integrated into an
automotive vehicle.   These integrated remote controls provide customer
convenience, appliance interoperability, increased safety, and enhanced vehicle
value.

Present in-vehicle integrated remote controls provide a "universal"
or programmable garage door opener which learns characteristics of an existing
transmitter then, when prompted by a user, generates an activation signal having the
same characteristics. One problem with such devices is the need to put a complex
electronic device within the vehicle, where space is a premium. Another problem
with such devices is the requirement that they operate together with existing remote

controls. Yet another problem is the difficulty experienced by users programming such devices to work with existing garage door opener receivers.

Another solution is to purchase a second receiver compatible with a new transmitter and then hard wire the second receiver into the existing garage door

5   opener circuit. Such installation is beyond the capabilities of some users.

What is needed is a universal remote controller that does not require complex electronics within the vehicle, is compatible with existing transmitters, is more easily set up by a vehicle owner and does not require wiring into the garage door opener circuitry.

10   SUMMARY OF THE INVENTION

The present invention provides a relay between radio frequency transmission schemes having different characteristics.

A system for controlling an appliance is provided. A radio receiver receives radio frequency control signals for controlling the appliance. The

15   controlling radio frequency signals have predetermined receiver characteristics. Each of at least one existing radio frequency transmitter is specifically designed to transmit wireless radio frequency control signals having these predetermined receiver characteristics to the radio receiver. A new wireless radio frequency transmitter has predetermined transmitter characteristics, at least one of which is not

20   compatible with the radio receiver. A radio relay learns the receiver characteristics from one of the existing transmitters and learns at least one transmitter characteristic from the new transmitter. Then, when an appliance radio frequency activation command is received from the new transmitter, the radio relay transmits a new radio frequency appliance activation command having the learned receiver characteristics.

25   In an embodiment of the present invention, the radio relay determines as one of the receiver characteristics whether the receiver operates using a fixed code or a variable code. If the receiver operates using a fixed code, the radio relay

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stores the fixed code. Other possible learned receiver characteristics include carrier frequency, code word, type of code, transmitter identifier, and the like.

In another embodiment of the present invention, the radio frequency control signals received by the radio receiver contain a rolling code. The receiver ignores control signals having a rolling code value within a rear window of possible rolling code values. The radio relay transmits radio frequency control signals to the radio receiver so as to place the existing transmitter from which the radio relay learned the receiver characteristics into the receiver rolling code value rear window. If the radio relay then receives a transmission from the existing transmitter, the radio relay may transmit a radio frequency control signal to the receiver having a rolling code value outside of the receiver rolling code value rear window.

In still another embodiment of the present invention, the radio relay determines from a radio frequency command received from the new transmitter whether the command is for a first appliance or a second appliance. The second appliance may be remotely controlled either wirelessly or through wired connections.

A method for controlling an appliance is also provided. A radio transmission is received from an existing wireless radio frequency transmitter transmitting radio frequency signals having a first set of transmission characteristics. Data representing these transmission characteristics is stored. A radio transmission from a new wireless transmitter is received. The new transmitter transmits radio frequency signals having a second set of transmission characteristics different from the first set of transmission characteristics. Data representing at least one characteristic from the second set of transmission characteristics is stored. An activation request is received from the new transmitter. The activation request is transmitted to the appliance with a radio frequency signal based on the first set of transmission characteristics.

A universal garage door opener is also provided. The garage door is controlled by a radio frequency receiver responsive to an existing radio frequency

transmitter. The receiver responds to an activation signal sent by the existing transmitter having a first set of signal characteristics. The garage door opener includes a wireless radio frequency receiver receiving radio frequency control signals transmitted with any one of a plurality of signal characteristics including the

5 first set of signal characteristics. A wireless radio frequency transmitter transmits radio frequency control signals having any one of the plurality of signal characteristics. Control logic in communication with the receiver, the transmitter and a user interface switches to a learn mode in response to the user interface. While in the learn mode, an activation signal transmitted by the existing transmitter

10 is received and the first set of signal characteristics is determined. In an operate mode, an activation request is received from a radio frequency signal having a second set of signal characteristics. The activation request is transmitted with a radio frequency signal having the first set of signal characteristics.

In an embodiment of the present invention, the control logic assigns

15 one of a plurality of channels to the first set of signal characteristics, thereby allowing the universal garage door opener to operate a plurality of radio frequency devices.

In still another embodiment of the present invention, the garage door opener includes a second transmitter for transmitting signals through AC wiring.

20 The control logic associates a received activation request with an appliance interconnected to the garage door opener through the AC wiring.

The above features, and other features and advantages of the present invention are readily apparent from the following detailed descriptions thereof when taken in connection with the accompanying drawings.

25 BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a block diagram illustrating an appliance control system according to an embodiment of the present invention;

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FIGURE 2 is a schematic diagram illustrating activation signal characteristics according to an embodiment of the present invention;

FIGURE 3 is a block diagram illustrating rolling code operation that may be used with the present invention;

5   FIGURE 4 is a block diagram illustrating an appliance controller according to an embodiment of the present invention;

FIGURE 5 is a block diagram of a wireless transceiver that may be used to implement the present invention;

FIGURE 6 is a block diagram of an alternative wireless transceiver
10   that may be used to implement the present invention;

FIGURE 7 is a schematic diagram of a user interface according to an embodiment of the present invention;

FIGURE 8 is a flow diagram illustrating radio relaying according to an embodiment of the present invention; and

15   FIGURE 9 is a schematic diagram of rolling code windowing according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figure 1, a block diagram illustrating an appliance control system according to an embodiment of the present invention is shown. An
20   appliance control system, shown generally by 20, allows one or more appliances to be remotely controlled using radio transmitters. In the example shown, radio frequency remote controls are used to operate garage door openers. However, the present invention may be applied to controlling a wide variety of appliances such as

other mechanical barriers, lighting, alarm systems, temperature control systems, and the like.

Appliance control system 20 includes garage 22 having two garage doors, not shown. First garage door opener (GDO) receiver 24 receives radio frequency control signals 26 for controlling a first garage door opener. First received control signals 26 have predetermined receiver characteristics for operation with GDO receiver 24. Garage 22 also includes second GDO receiver 28 receiving radio frequency control signals 30 for controlling a second garage door opener. Second received control signals 30 also have predetermined receiver characteristics that may be the same or different from those for first received control signals 26. First existing transmitter (ET1) 32 transmits wireless radio frequency control signals 34 having predetermined receiver characteristics compatible with GDO receiver 24. Second existing transmitter (ET2) 36 transmits wireless radio frequency control signals 38 having predetermined receiver characteristics compatible with second GDO receiver 28.

A user of appliance control system 20 may wish to add a new transmitter to system 20. For example, vehicle-based transmitter 40 may be installed in vehicle 42, which may be parked in garage 22. Vehicle-based transmitter 40 generates new transmitted control signals 44 having at least one characteristic making new transmitted control signals 44 not compatible with at least one of GDO receiver 24 and GDO receiver 28.

Appliance control system 20 includes radio relay 46 capable of learning characteristics of first transmitted control signals 34 from first existing transmitter 32, second transmitted control signals 38 from second existing transmitter 36, or both. Radio relay 46 also learns at least one characteristic of new transmitted control signals 44 from vehicle-based transmitter 40. When radio relay 46 receives an appliance radio frequency activation command from vehicle-based transmitter 40, radio relay 46 transmits a new radio frequency appliance activation command to GDO receiver 24 or GDO receiver 28 using the characteristics of first received control signals 26 or second received control signals 30, respectively.

The operation of existing transmitters 32, 36 following the addition of radio relay 46 may vary depending upon the characteristics of transmitted control signals 34, 38. For some implementations, existing transmitter 36 will still directly affect the operation of receiver 28. In other implementations, radio relay 46 will

5   inhibit the direct activation of receiver 24 by existing transmitter 32. Radio relay 46 will respond to activation signals from existing transmitter 32 by transmitting a new activation signal to receiver 24.

Radio relay 46 may include AC connector 48 through which radio relay 46 receives electrical power. Radio relay 46 may be programmed to send a

10   radio frequency activation signal through AC connector 48 based on an activation signal received from vehicle-based transmitter 40 and/or existing transmitter 32, 36. In this manner, one or more appliances linked to radio relay 46 through a power grid such as, for example, lamp 50, alarm system 52, and the like, can be remotely controlled.

15   Referring now to Figure 2, a schematic diagram illustrating activation signal characteristics according to an embodiment of the present invention is shown. Information transmitted in an activation signal is typically represented as a binary data word, shown generally by 60. Data word 60 may include one or more fields, such as transmitter identifier 62, function indicator 64, code word 66, and the like.

20   Transmitter identifier (TRANS ID) 62 uniquely identifies a remote control transmitter. Function indicator 64 indicates which of a plurality of functional buttons on the remote control transmitter were activated. Code word 66 helps to prevent misactivation and unauthorized access.

Several types of codes 66 are possible. One type of code is a fixed

25   code, wherein each transmission from a given remote control transmitter contains the same code 66. In contrast, variable code schemes change the bit pattern of code 66 with each activation. The most common variable code scheme, known as rolling code, generates code 66 by encrypting a counter value. After each activation, the counter is incremented. The encryption technique is such that a sequence of

30   encrypted counter values appears to be random numbers.

Data word 60 is converted to a baseband stream, shown generally by 70, which is an analog signal typically transitioning between a high voltage level and a low voltage level. Various baseband encoding or modulation schemes are possible, including polar signaling, on-off signaling, bipolar signaling, duobinary

5   signaling, Manchester signaling, and the like. Baseband stream 70 has a baseband power spectral density, shown generally by 72, centered around a frequency of zero.

Baseband stream 70 is converted to a radio frequency signal through a modulation process shown generally by 80. Baseband stream 70 is used to modulate one or more characteristics of carrier 82 to produce a broadband signal,

10   shown generally by 84. Modulation process 80, mathematically illustrated in Figure 2, implements a form of amplitude modulation commonly referred to as on-off keying. As will be recognized by one of ordinary skill in the art, many other modulation forms are possible, including frequency modulation, phase modulation, and the like. In the example shown, baseband stream 70 forms envelope 86

15   modulating carrier 82. As illustrated in broadband power spectral density 88, the effect in the frequency domain is to shift baseband power spectral density 72 to be centered around the carrier frequency, f, of carrier 82.

Referring now to Figure 3, a block diagram illustrating rolling code operation that may be used with the present invention is shown. Remotely

20   controlled systems using rolling code require crypt key 100 in both the transmitter and the receiver for normal operation. In a well-designed rolling code scheme, crypt key 100 is never transmitted from the transmitter to the receiver. Typically, crypt key 100 is generated using key generation algorithm 102 based on transmitter identifier 62 and a manufacturing (MFG) key 104. Crypt key 100 and transmitter

25   identifier 62 are then stored in a particular transmitter. Counter 106 is also initialized in the transmitter. Each time an activation signal is sent, the transmitter uses encrypt algorithm 108 to generate rolling code 110 from counter 106 using crypt key 100. The transmitted activation signal includes rolling code 110 and transmitter identifier 62.

A rolling code receiver is trained to a compatible transmitter prior to operation. The receiver is placed into a learn mode. Upon reception of an activation signal, the receiver extracts transmitter identifier 62. The receiver then uses key generation algorithm 102 with manufacturing key 104 and received

5   transmitter identifier 62 to generate crypt key 100 identical to the crypt key used by the transmitter. Newly generated crypt key 100 is used by decrypt algorithm 112 to decrypt rolling code 110, producing counter 114 equal to counter 106. The receiver then saves counter 114 and crypt key 100 associated with transmitter identifier 62. As is known in the encryption art, encrypt algorithm 108 and decrypt

10   algorithm 112 may be the same algorithm.

In normal operation, when the receiver receives an activation signal, the receiver first extracts transmitter identifier 62 and compares transmitter identifier 62 with all learned transmitter identifiers. If no match is found, the receiver rejects the activation signal. If a match is found, the receiver retrieves crypt key 100

15   associated with received transmitter identifier 62 and decrypts rolling code 110 from the received activation signal to produce counter 114. If received counter 106 matches counter 114 associated with transmitter identifier 62, activation proceeds. As will be discussed in greater detail below, received counter 106 may also exceed stored counter 114 by a preset amount for successful activation.

20   Another rolling code scheme generates crypt key 100 based on manufacturing key 104 and a "seed" or random number. An existing transmitter sends this seed to an appliance receiver when the receiver is placed in learn mode. The transmitter typically has a special mode for transmitting the seed entered, for example, by pushing a particular combination of buttons. The receiver uses the

25   "seed" to generate crypt key 100. As will be recognized by one of ordinary skill in the art, the present invention applies to the use of a "seed" for generating a crypt key as well as to any other variable code scheme.

Referring now to Figure 4, a block diagram illustrating an appliance controller according to an embodiment of the present invention is shown. Radio

30   relay 46 includes wireless transceiver 120 transmitting and receiving wireless signals

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through antenna 122. Wireless transceiver 120 forwards demodulated data to control logic 124 and receives data from control logic 124 for modulation. Control logic 124 can extract activation signal characteristics from received data and/or may receive characteristics directly from wireless transceiver 120. Control logic 124

5   stores characteristics in non-volatile memory such as flash memory 126. User interface 128 forwards user input to control logic 124 and receives commands from control logic 124 to provide user output. Control logic 124 is preferably implemented as a microcontroller. However, control logic 124 may be implemented with any combination of discrete logic, analog electronic components,

10   programmable logic, microprocessors, and the like. In addition, various components illustrated in Figure 4 may be included on a single integrated circuit for decreased cost in mass production.

Radio relay 46 may also include X-10 transceiver 130 for sending and receiving radio frequency signals over a power grid such as residential wiring.

15   X-10 is a standard defining a signal which includes a pattern of 1 msec bursts of a 120 kHz carrier synchronized with the zero crossings of an AC power signal. Circuitry implementing the X-10 standard is well known in the art and includes the TW523 two-way power line interface from X-10 Inc., Closter, New Jersey. X-10 transceiver 130 interfaces with AC power supply 132 to achieve signal transmission

20   over AC connector 48. AC power supply 132 also supplies electrical power for the remaining elements of radio relay 46.

Referring now to Figure 5, a block diagram of a wireless transceiver that may be used to implement the present invention is shown. Wireless transceiver 120 includes a receiver section, shown generally by 140, and a transmitter section,

25   shown generally by 142. Receiver section 140 includes antenna 144, variable oscillator 146, mixer 148, intermediate filter 150, detector 152 and control logic 124. A radio frequency signal is received by antenna 144. Mixer 148 accepts the received signal and a carrier frequency sinusoid from variable oscillator 146. Mixer 148 remodulates the received signal so that the broadband spectrum is centered

30   about frequencies which are the sum and difference of the received signal carrier frequency and the variable oscillator carrier frequency. Control logic 124 varies the

frequency of variable oscillator 146 until one of the remodulated components falls within the bandwidth of fixed, narrow band intermediate filter 150. Filter 150 passes this component and rejects all other signals. As will be recognized by one of ordinary skill in the art, receiver 140 functions as a superheterodyne receiver.

5   Detector 152 converts the filtered signal into a baseband signal. Detector 152 may be implemented as a simple envelope detector. When control logic 124 receives valid data from detector 152, variable oscillator 146 is tuned to permit a received signal to pass through intermediate filter 150. If control logic 124 knows the intermediate frequency of filter 150, control logic 124 can determine the carrier

10   frequency of the received signal.

Transmitter section 142 includes antenna 154, which may be the same as antenna 144, variable gain amplifier 156, modulator 158, variable oscillator 146 and control logic 124. For transmitting, control logic 124 sets variable oscillator 146 to the desired carrier frequency. Control logic 124 then modulates the carrier

15   frequency with modulator 158, here modeled as a switch. Control logic 124 sets variable gain amplifier 156 to provide the maximum allowed signal strength. The amplified signal is transmitted by antenna 154.

Components which make up wireless transceiver 120 in Figure 5 are well known in the art of radio communications. Examples of circuits which may be

20   used to implement wireless transceiver 120 can be found in U.S. Patent No. 5,614,891, titled Vehicle Accessory Trainable Transmitter; U.S. Patent No. 5,661,804, titled Trainable Transceiver Capable of Learning Variable Codes; and U.S. Patent No. 5,686,903, titled Trainable RF Transceiver; each of which is herein incorporated by reference in their entirety.

25   Referring now to Figure 6, a block diagram of an alternative wireless transceiver that may be used to implement the present invention is shown. Wireless transceiver 120 includes receiver section 170 and transmitter section 172. Receiver section 170 includes antenna 174, sampler 176, digital radio frequency memory (DRFM) 178, detector 180 and control logic 124. Control logic 124 monitors the

30   output of detector 180, which receives input from antenna 174. When control logic

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124 detects valid data from detector 180, control logic 124 waits until a period when the carrier is present on the signal received with antenna 174. Control logic 124 asserts the "record" input to DRFM 178. By asserting "play" and "select," control logic 124 can shift the sampled carrier from DRFM 178 into control logic 124 over

5   bus 182.

Transmitter section 172 includes antenna 184, which may be the same as antenna 174, filter 186, variable gain amplifier 188, DRFM 178 and control logic 124. Control logic 124 can load DRFM 178 with a sampled carrier stream by asserting "select" and "record," then shifting the carrier stream into DRFM 178 on

10   bus 182. The bit stream representing a carrier may have been previously received and sampled or may be preloaded into control logic 124. Control logic 124 generates a modulated carrier on DRFM output 190 by asserting the "play" control line with the desired data word. The amplitude modulated signal on DRFM output 190 is amplified by variable gain amplifier 188 and filtered by filter 186 before

15   transmission by antenna 184.

A DRFM transceiver similar to the system pictured in Figure 6 is described in U.S. Patent Application Serial No. 10/306,077, titled Programmable Transmitter And Receiver Including Digital Radio Frequency Memory, filed November 27, 2002, which is herein incorporated by reference in its entirety.

20   Referring now to Figure 7, a schematic diagram of a user interface according to an embodiment of the present invention is shown. Radio relay 46 includes channel pushbutton 200, channel indicator lamp 202, transmitter pushbutton 204, transmitter indicator lamp 206, channel selector switch 208, X-10 house switch 210 and X-10 unit switch 212. Channel pushbutton 200 is used to program radio

25   relay 46 to a particular appliance. The user begins by setting channel selector switch 208 to the appropriate channel. The embodiment illustrated has five wireless channels (RF1-RF5) and one X-10 channel. If channel selector switch 208 is set to a wireless channel, and channel pushbutton 200 is pushed, channel indicator lamp 202 will flash indicating radio relay 46 is waiting to receive an activation signal

30   from an existing transmitter. The user then activates an existing transmitter. Radio

relay 46 receives the activation signal on antenna 122 and stores characteristics of the received signal necessary to activate the controlled appliance. If the appliance activation signal was received and characteristics properly stored, channel indicator lamp 202 will glow steadily to indicate successful wireless channel training.

5   If the appliance is to be controlled through the power grid, channel selector switch 208 is set to X-10. X-10 house switch 210 and X-10 unit switch 212 are set to match the corresponding house switch and unit switch of an X-10 receiver module connected to the controlled appliance. The user then pushes channel pushbutton 200. Radio relay 46 associates house switch 210 and unit switch 212 10   settings with channel X-10. Channel indicator lamp 202 then glows steadily to indicate success.

          Any time after the channel is programmed, the user may associate a new transmitter with the channel. The user sets channel selector switch 208 to the desired channel and pushes transmitter pushbutton 204. Transmitter indicator lamp 15   206 then flashes indicating radio relay is ready for transmitter programming. The user then activates the new transmitter. Radio relay 46 receives the activation signal on antenna 122 and stores at least one characteristic of the received signal associated with the selected channel. Radio relay 46 then turns on transmitter indicator lamp 206 for a short period to indicate success.

20   Referring now to Figure 8, a flow diagram illustrating radio relaying according to an embodiment of the present invention is shown. As will be appreciated by one of ordinary skill in the art, the operations illustrated are not necessarily sequential operations. Similarly, operations may be performed by software, hardware, or a combination of both. The present invention transcends any 25   particular implementation and the aspects are shown in sequential flow chart form for ease of illustration.

          The radio relay functions in one of two modes, as indicated by block 220. The default mode is operate mode. The radio relay may be placed into learn mode through the user interface as described with regard to Figure 7 above. In

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addition, a switch may be provided to allow the user to specifically place the radio relay in either learn mode or operate mode. The radio relay may switch from learn mode to operate mode upon completion of a learn operation, after a timeout period, upon receiving specific user input, or the like.

5   If the radio relay is in learn mode, user input is received, as in block 222. A check is made to determine if a channel is being trained, as in block 224. This check may be based on user input. If so, a check is made to determine whether or not the channel to be trained is a wireless channel, as in block 226. This determination may also be based upon user input. If a wireless channel is being

10   trained, the radio relay waits to receive transmission from an existing transmitter, as in block 228. This transmission may include one or more of transmitter identifier 62, a random number or "seed" value, fixed or rolling code 66, function code 64, and the like. If a valid transmission is received, the radio relay stores characteristics of the existing transmitter, as in block 230. For rolling code systems, if the radio

15   relay stores the same transmitter identifier as the existing transmitter, the radio relay becomes a clone of the existing transmitter. Operation of such a radio relay is described with regard to Figure 9 below. Alternatively, the radio relay can create a new transmitter identifier to be stored as a characteristic of the existing transmitter. The rolling code receiver can then be trained to the radio relay. This

20   allows a receiver to recognize the existing transmitter and the radio relay as separate transmitters.

          If the channel being trained is not a wireless channel, the radio relay inputs and stores X-10 information, as in block 232. This information can include the house and unit selections input by the user. As will be recognized by one of

25   ordinary skill in the art, other types of channels may also be trained.

          Returning to block 224, the radio relay may be programmed to a new transmitter. The radio relay waits to receive a transmission from the new transmitter, as in block 234. If the received transmission is valid, the radio relay associates the new transmitter information with the selected channel, as in block

30   236. A wide variety of new transmitters may be trained in this manner. The new

transmitter may be vehicle-based, wall mounted, or handheld. The radio relay may learn an entire set of operating characteristics from the new transmitter. Alternatively, or in addition, the radio relay may assume all but at least one characteristic, which is learned from the new transmitter. This characteristic may be, for example, the transmitter identifier. The radio relay may test the assumption that only at least one characteristic must be learned by examining the activation signal received from the new transmitter to determine the transmitter type.

Considering again block 220, if the radio relay is in operate mode, the radio relay waits to receive a transmission from a transmitter in block 238. If a valid transmission is received, the radio relay retrieves channel information associated with the transmitter. This may be done, for example, by associating the transmitter identifier for each transmitter with the characteristics required to activate the appliance controlled by that channel. The radio relay then transmits based on the retrieved channel information, as in block 242.

Referring now to Figure 9, a schematic diagram of rolling code windowing according to an embodiment of the present invention is shown. A code wheel, shown generally by 250, represents the set of possible counter values or corresponding rolling code values for a particular rolling code scheme. This set of values may be represented as a circle or wheel due to the finite number of bits used to express the counter value or rolling code value. Thus, if the counter or rolling code value is incremented enough times, the set will cycle back to the original value. The cyclic nature of the value set is used to advantage by rolling code receivers.

Code wheel 250 within an appliance receiver can be subdivided into four groups. The first group is a single value, represented by present receiver value 252. Present receiver value 252 is the current value of counter or rolling code expected in the next reception of an activation signal. In association with each received activation signal, present receiver value 252 advances to the next spot in code wheel 250. This may be represented in Figure 9 by a clockwise movement of present receiver value 252 around code wheel 250. Alternatively, code wheel 250 can be thought to rotate in a counterclockwise direction keeping present receiver

value 252 in the top position on Figure 9. A second group of values is contained in forward window 254. Values in forward window 254 immediately follow present receiver value 252 in the sequence of code wheel 250. A third group of values are contained in resynchronization window 256 sequentially following forward window

5   254. A fourth set of values are contained in rear window 258. Values in rear window 258 immediately precede present receiver value 252. In the illustration shown, values in rear window 258 begin at the end of resynchronization window 256. However, there may be a gap of values between resynchronization window 256 and rear window 258.

10   With reference also to Figure 3, operation of a typical rolling code receiver is based on comparing a value received in an activation signal with present receiver value 252. The following discussion will reference transmitter counter 106 as the value received in the activation signal and receiver counter 114 as present receiver value 252. However, transmitted rolling code value 110 may also be

15   compared against a present receiver rolling code value.

During normal operation, when a rolling code appliance receiver receives an activation signal, the received transmitter identifier is compared against those known by the receiver. If a match is found, the receiver retrieves receiver counter value 114 and compares this against transmitter counter 106 received in the

20   activation signal. If a match occurs, the appliance is activated. Due to the limited transmission range of radio frequency remote control transmitters, some allowance is made for attempting to activate the transmitter outside the range of the appliance receiver. If the receiver receives transmitter counter value 106 within forward window 254, appliance activation occurs.

25   An additional acceptance feature is provided by resynchronization window 256. If the appliance receiver receives transmitter counter value 106 within resynchronization window 256, the receiver remembers transmitter counter 106 but does not activate the appliance. If the next transmission received by the appliance receiver contains the next sequential transmitter counter 106, the appliance receiver

30   activates the appliance and resets present receiver value 252 to the second received

transmitter counter value 106. Since it is human nature to press a transmitter activation button a second time if the first press did not work, resynchronization window 256 provides a means for safely resynchronizing the remote control transmitter with the appliance receiver.

5   If the appliance receiver receives transmitter counter value 106 within rear window 258, the receiver ignores the activation signal. This prevents a reflected transmission from twice activating the receiver. In addition, an unauthorized user cannot intercept an activation signal and retransmit the stolen signal to gain access.

10   An embodiment of the present invention uses code wheel 250 to create a clone of an existing transmitter and permit access to a remotely controlled appliance without having to retrain the rolling code appliance receiver. When learning the characteristics of an existing rolling code transmitter, the radio relay uses the received transmitter identifier 62 to generate crypt key 100 identical to the

15   crypt key in the existing transmitter and the appliance receiver trained to the existing transmitter. The radio relay uses crypt key 100 to decrypt rolling code 110, received in the training signal, to obtain transmitter counter 106. The radio relay advances this counter value to correspond with a value in the trained receiver lying within resynchronization window 256. The radio relay then transmits two sequential

20   transmitter counter values, using characteristics learned from the existing transmitter, to the trained receiver. This places transmitter counter 106 in the existing transmitter within rear window 258 of receiver code wheel 250, as illustrated by existing transmitter value 260. Thus, the appliance receiver will now ignore all transmissions from the existing transmitter used to train the radio relay.

25   In order to continue effective operation with the existing transmitter, the radio relay will listen for any transmission from the existing transmitter. If such a transmission is received by the radio relay, the radio relay retransmits the activation signal using a counter value expected as present receiver value 252 by the appliance receiver. If the radio relay is no longer needed, the appliance receiver

30   may be retrained to the existing transmitter.

While embodiments of the invention have been illustrated and described, it is not intended that these embodiments illustrate and describe all possible forms of the invention. Rather, the words used in the specification are words of description rather than limitation, and it is understood that various changes

5   may be made without departing from the spirit and scope of the invention.